Docket No.: H6790.0004/P004
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Masaki Kato et al.

Application No.: 10/699,878

Confirmation No.: 3496

Filed: November 4, 2003

Art Unit: 1756

For: OPTICAL INFORMATION RECORDING MEDIUM AND PROCESS FOR RECORDING THEREON

Examiner: M. J. Angebranndt

SUBMISSION OF CERTIFIED ENGLISH TRANSLATION OF JAPANESE PATENT APPLICATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant herewith provides a certified translation of the following priority document.

Country	Application No.	Date
Japan	2002-322306	November 6, 2002

Dated: August 24, 2007

Respectfully submitted,

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DECLARATION

I, Takashi Ota, the translator of the attached document, do hereby certify that to the best of my knowledge and belief, the attached documents are true English translations of Japanese Patent Application No. 2002-322306.

Signed, this tenth day of July, 2007

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Date of Filing: November 6, 2002
Japanese Patent Application No.: 2002-322306

[Name of Document]	Application for Patent
[Reference No.]	0205918
[Date of Filing]	November 6, 2002
[Addressee]	Commissioner of Japan Patent Office Shinichiro Ota
[Int'l Class]	G11B 7/24 511
[Title of the Invention]	Optical Information Recording Medium and Optical Information Recording Method
[Numbers of Claims]	13
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[Indication of Fee]	
[Prepayment No.]	007777
[Amount of Payment]	21,000 Yen
[List of Attached Documents]	

[Name of Document] Specification 1
[Name of Document] Drawings 1
[Name of Document] Abstract 1
[General Power of Attorney No.] 0010869

[Necessity of Proof] Necessary
[Name of Document] Specification
[Title of the Invention] Optical Information Recording Medium and Optical Information Recording Method

[Scope of Claims]

[Claim 1]

An optical information recording medium at least including a recording layer and a reflective layer which are disposed on a transparent substrate, wherein the optical information recording medium records, erases, and/or rewrites information by irradiating and scanning the recording layer with focused light to form and erase recording marks on the recording layer, the optical information recording medium being characterized in that the recording layer includes an alloy or an intermetallic compound, which mainly has Ga, Ge, Sb, and Te in a compositional ratio and is represented by a formula of GaxGey(SbzTe1-z)1-x-y,
wherein x, y, and z represent an atomic ratio of a positive real number which is less than 1, and satisfy following conditions of:

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

$x + y \leqq 0.1$.

[Claim 2]

The optical information recording medium according to claim 1, characterized in that a content amount of the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te in the recording layer, is equal to or higher than 90 atomic percent.

[Claim 3]

The optical information recording medium according to claim 1 or 2, characterized in that the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, includes Mn in a range of 0.01 to 0.04 in an atomic ratio.

[Claim 4]

The optical information recording medium according to any one of claims 1 to 3, characterized in that scanning speed used for recording, erasing and/or rewriting operations is preformatted, and the scanning speed is from 9.6 to 33.6 m/s.

[Claim 5]

The optical information recording medium according to any one of claims 1 to 4, characterized in that the reflective layer includes Ag or an alloy including 95 mole % or more of Ag.

[Claim 6]

The optical information recording medium according to any one of claims 1 to 5, characterized by including layers mainly including oxide, which are adjacent to the recording layer and are in a side of the substrate and/or the reflective layer, wherein thickness of the layer is in a range of 1 to 5 nm.

[Claim 7]

The optical information recording medium according to any one of claims 1 to 6, characterized by undergoing initialization (operation to crystallize the recording layer in an information recording area of the optical information recording medium before being used) by irradiating and scanning the recording layer with a high power laser beam at scanning speed of 1 to 2.5 m/s.

[Claim 8]

A sputtering target for producing an optical information recording medium, characterized by including an alloy or an intermetallic compound, which mainly includes Ga, Ge, Sb, and Te in a compositional ratio and is represented by a formula of $Ga_xGe_y(Sb_zTe_{1-z})_{1-x-y}$,

wherein x, y, and z represent an atomic ratio of a positive real number, which is less than 1, and satisfy following conditions of:

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

$x + y \leqq 0.1$.

[Claim 9]

The sputtering target according to claim 8, characterized in that a content amount of the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, is equal to or higher than 90 atomic percent.

[Claim 10]

The sputtering target according to claim 8 or 9, characterized in that the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, includes Mn in a range of 0.01 to 0.03 in an atomic ratio.

[Claim 11]

An initialization method for an optical information recording medium according to any one of claims 1 to 7, characterized by initializing the optical information recording medium (operation to crystallize the recording layer in an information recording area of the optical information recording medium before being used) by irradiating and scanning the optical information recording medium with a high power laser beam at scanning speed in a range of 1 to 2.5 m/s.

[Claim 12]

A recording method of the optical information recording medium according to any one of claims 1 to 7, characterized by irradiating and scanning the optical information recording medium by using pulses with irradiation intensities P of Pw and Pb alternately so as to form recording marks, wherein a relation of $n = 2m$ (n is an even number) or $n = 2m + 1$ (n is an odd number) is satisfied when a record mark length is represented by nTw (n is a natural number) with respect to

a reference clock period of Tw, the record marks are erased by irradiating and scanning the optical information recording medium with light having constant intensity P of Pe, and Pw, Pe, and Pb satisfy a condition of Pw > Pe > Pb.

[Claim 13]

The recording method according to claim 12, characterized in that n and m satisfy a condition of n = m + 1 when the scanning speed is equal to or lower than 22.4 m/s and Tw is equal to or higher than 14.4 ns.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a phase change optical information recording medium, and particularly to a CD-RW and a recording method of the CD-RW.

[0002]

[Background Art]

In a compact disc (CD) and a DVD, information is reproduced based on a change in intensity of a light beam reflected from the optical information recording media. In a read only optical disc, a substrate having projections and depressions thereon is provided to cause a phase difference in the reflected light beam. Thereby, interference occurs to induce the change in the intensity.

On the other hand, in a recordable optical information recording medium, the change in the intensity of the reflected light beam is induced by forming micro domains having different optical properties in a recording layer provided on the substrate of the recordable optical information recording medium. Specific examples of materials used for the recording layer include an organic coloring material in CD recordable (CD-R), and DVD recordable (DVD+R) discs, a phase change recording material in CD rewritable (CD-RW) and DVD rewritable (DVD+RW) discs and the like.

In any case, information is recorded on the optical discs by irradiating a focused light beam in the vicinity of the recording layer, which changes a state of the micro domains. Then, due to the difference in the optical properties in the micro domains, phase difference and intensity difference occur.

[0003]

When a phase change material is used in the recording layer, recording marks may be formed and erased by using a reversible phase change between a crystalline phase and an amorphous phase, which is used in a recording operation. Thereby, a rewritable optical information recording medium may be provided. In addition, the phase change between the crystalline phase and the amorphous phase may be controlled based on thermal hysteres of a rapid cooling operation and a slow cooling operation of a material. Therefore, information may be recorded and erased by modulating intensity of a light beam to be irradiated. Thereby, there is an advantage that a recording apparatus may be produced at low cost. In addition, since the recorded information may be reproduced in a read only apparatus, the phase change recording medium has been widely employed.

In recent years, demands have been increasing on optical discs to have larger capacity and to operate at higher speed as a capacity of electronic information and speed of information processing are increased. An optical information recording medium having larger density is a most effective means to satisfy such demands. To increase the density of the optical information recording medium, for example a change in an optical system used in a recording operation (increase in a numerical aperture NA and shortening of wavelength), a change in a modulation method, etc. are considered. Such change may be for example seen in a transition from CD to DVD. However, a conventional CD reproducing apparatus may not reproduce information recorded on such a high density DVD. Incompatibility in reproduction is a large problem in a commercially distributed optical information recording

medium. If the compatibility is highly considered, increase in speed of an operation becomes a biggest challenge.

[0004]

It is difficult for a rewritable optical information recording medium using a phase change material to have higher recording and/or reproducing speed as compared with higher recording and/or reproducing speed of a write once optical information recording medium using a coloring matter, on which information may be recorded only once. To form recording marks on the rewritable optical information recording medium at higher speed, a light beam with higher recording power may be irradiated as in a case of using the write once optical information recording medium having the coloring matter. At high speed, however, the recording marks may not be erased in the rewritable optical information recording medium using the phase change material. In other words, a scanning operation at higher speed may not create a "slow cooling" condition required for forming a crystalline phase in which the recording marks are erased.

Therefore, increase in scanning speed of a rewritable optical disc using the phase change is slower than scanning speed of an optical disc using a coloring matter. For example, a CD-R medium now available may be recorded at 40-speed (scanning speed of 48 m/s and a channel bit rate of 1.6 Gbps), and a CD-RW medium may be recorded at 10-speed (scanning speed of 12 m/s and a channel bit rate of 41 Mbps).

[0005]

Further, patent applications disclosed prior to the present application are as follows.

Patent application 1 discloses an optical information recording medium using $((Sb_xTe_{1-x})_yGe_{1-y})_zM_{1-z}$ (wherein x, y and z satisfy a following condition of: $0.7 \leqq x \leqq 0.9$, $0.8 \leqq y < 1$, and $0.88 \leqq z < 1$, and M represents In and/or Ga) as a material for a recording layer. However, specified compositional ratios are in wide ranges, and examples described therein show only recording layer in which M is In and does not show data for verifying effects of the use

of Ga as M. Also, the patent application 1 does not describe necessity of Ga and great differences between Ga and In, which are described in the present invention. In addition, the patent application 1 does not refer to ensuring storage reliability and improvement of direct overwriting properties at high scanning speed of 20 m/s or higher, which are objects of the present invention.

Patent application 2 discloses an optical information recording medium having a recording layer mainly including GeSbTe and further including an arbitral metal element selected among a wide variety of metal elements, which is capable of overwriting at high speed. In example 16 of the patent application 2, an optical information recording medium using Ga0.06Ge0.06Sb0.68Te0.22 is disclosed. However, a term "high speed" used in the patent application 2 is at highest 10 m/s as specified for example in claim 31 of the patent application 2. The patent application 2 does not describe improvement in overwriting properties at scanning speed of 20 m/s or higher as described in the present invention. Also, an alloy composition described in the example 16 of the patent application 2 is out of ranges of an alloy composition, which is specified in the present invention. In addition, the patent application 2 neither discloses nor indicates effectiveness of Ga, which is pointed out by the present invention.

[0006]

Patent applications 3 and 4 disclose an optical information recording medium having a recording layer which mainly includes SbTe and further includes an arbitral element selected among a wide variety of elements. However, the patent applications 3 and 4 lack concrete description of a GaGeSbTe alloy. Further, the patent applications 3 and 4 neither disclose nor indicate the direct overwriting properties at scanning speed of 20 m/s or higher, which are an object of the present invention, and the effectiveness of Ga which is pointed out by the present invention.

Patent application 5 discloses an optical information recording medium having a recording layer which mainly includes the GaGeSbTe. However, since the recording layer mainly includes a GeTe alloy (or an intermetallic compound), the recording layer has clearly different compositional ranges and properties from the materials of the present invention including a Sb-Te eutectic alloy to which a trace amount of a metal element is added.

[0007]

[Patent Application 1]

Japanese Patent Application Laid-open (JP-A) No. 2000- 313170.

[Patent Application 2]

Japanese Patent Application Laid-open (JP-A) No. 2001-56958.

[Patent Application 3]

Japanese Patent Application Laid-open (JP-A) No. 2001-236690.

[Patent Application 4]

Japanese Patent (JP-B) No. 3255051(JP-A No. 10-172179).

[Patent Application 5]

Japanese Patent (JP-B) No. 2629749(JP-A No. 01-138634).

[0008]

[Problems to be Solved]

An object of the present invention is to provide a widely spread optical information recording medium, particularly a CD-RW, on which a direct overwriting operation may be performed at high speed, and a recording method of the optical information recording medium.

[0009]

[Means for Solving Problems]

The problems are solved by following inventions 1) through 13) [hereinafter, referred to as inventions 1] through 13)].

1) An optical information recording medium at least including a recording layer and a reflective layer which are disposed on a transparent substrate, wherein the optical information recording medium records, erases, and/or rewrites information by irradiating and scanning the recording layer with focused light to form and erase

recording marks on the recording layer, the optical information recording medium being characterized in that the recording layer includes an alloy or an intermetallic compound, which mainly has Ga, Ge, Sb, and Te in a compositional ratio and is represented by a formula of $Ga_xGe_y(Sb_zTe_{1-z})_{1-x-y}$,

wherein x, y, and z represent an atomic ratio of a positive real number which is less than 1, and satisfy following conditions of:

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

$x + y \leqq 0.1$.

2 The optical information recording medium according to 1), characterized in that a content amount of the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te in the recording layer, is equal to or higher than 90 atomic percent.

3) The optical information recording medium according to 1) or 2), characterized in that the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, includes Mn in a range of 0.01 to 0.04 in an atomic ratio.

4) The optical information recording medium according to 1) to 3), characterized in that scanning speed used for recording, erasing and/or rewriting operations is preformatted, and the scanning speed is from 9.6 to 33.6 m/s.

5) The optical information recording medium according to 1) to 4), characterized in that the reflective layer includes Ag or an alloy including 95 mole % or more of Ag.

6) The optical information recording medium according to any one of 1) to 5), characterized by including layers mainly including oxide, which are adjacent to the recording layer and are in a side of the substrate and/or the reflective layer, wherein thickness of the layers is in a range of 1 to 5 nm.

7) The optical information recording medium according to

any one of 1) to 6), characterized by undergoing initialization (operation to crystallize the recording layer in an information recording area of the optical information recording medium before being used) by irradiating and scanning the recording layer with a high power laser beam at scanning speed of 1 to 2.5 m/s.

8)

A sputtering target for producing an optical information recording medium, characterized by including an alloy or an intermetallic compound, which mainly includes Ga, Ge, Sb, and Te in a compositional ratio and is represented by a formula of $Ga_xGe_y(Sb_zTe_{1-z})_{1-x-y}$,

wherein x, y, and z represent an atomic ratio of a positive real number, which is less than 1, and satisfy following conditions of:

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

$x + y \leqq 0.1$.

9)

The sputtering target according to 8), characterized in that a content amount of the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, is equal to or higher than 90 atomic percent.

10)

The sputtering target according to 8) or 9), characterized in that the alloy or the intermetallic compound, which mainly includes Ga, Ge, Sb, and Te, includes Mn in a range of 0.01 to 0.03 in an atomic ratio.

11)

An initialization method for an optical information recording medium according to any one of 1) to 7), characterized by initializing the optical information recording medium (operation to crystallize the recording layer in an information recording area of the optical

information recording medium before being used) by irradiating and scanning the optical information recording medium with a high power laser beam at scanning speed in a range of 1 to 2.5 m/s.

12)

A recording method of the optical information recording medium according to any one of 1) to 7), characterized by irradiating and scanning the optical information recording medium by using pulses with irradiation intensities P of Pw and Pb alternately so as to form recording marks, wherein a relation of $n = 2m$ (n is an even number) or $n = 2m + 1$ (n is an odd number) is satisfied when a record mark length is represented by nTw (n is a natural number) with respect to a reference clock period of Tw, the record marks are erased by irradiating and scanning the optical information recording medium with light having constant intensity P of Pe, and Pw, Pe, and Pb satisfy a condition of $Pw > Pe > Pb$.

13)

The recording method according to 12), characterized in that n and m satisfy a condition of $n = m + 1$ when the scanning speed is equal to or lower than 22.4 m/s and Tw is equal to or higher than 14.4 ns.

[0010]

Hereinafter, the present invention is described in detail.

Fig. 1 is a sectional view (schematic diagram) of an example of an optical information recording medium according to the present invention. The optical information recording medium of the present invention is required to have at least a recording layer 3 and a reflective layer 5 on a transparent substrate 1. A light beam used for recording, erasing, and/or reproducing information enters the optical information recording medium from the substrate illustrated underside of Fig. 1. The substrate 1 preferably has high transmittance in wavelengths of the light beam used for recording, erasing, and/or reproducing operations. Also, the substrate 1 has high strength. Materials of such substrate for example include glass,

ceramic, and resin. Among the materials, the substrate made with a resin is preferable in terms of strength, production cost, and productivity. In terms of high strength and low birefringence, an acrylic resin, and a polycarbonate resin are particularly preferable.

The substrate may have a guide groove (groove) for recording and reproducing light. Dimensions such as depth and width of the guide groove are optimized depending on a wavelength of a light beam used for the recording and reproducing operations, a numerical aperture (NA) and aberration of an objective lens which are used for focusing the light, and the like. For example, in a CD-RW using an optical system with a wavelength of 780 nm and a NA of 0.50, the groove width and the groove depth are preferably from 500 to 650 nm and from 30 to 50 nm, respectively, and are more preferably from 580 to 610 nm and from 32 to 44 nm, respectively. The guide groove may wobble, and preformatted address information may be encoded in the wobbling. An address preformatting system for example includes an ATIP (absolute time in pregroove) system in a CD-R and a CD-RW, in which frequency of the wobbling is modulated, and an ADIP (address in pregroove) system in a DVD+RW and a DVD+R, in which the phase of the wobbling is modulated.

[0011]

A material for the recording layer 3 is an alloy and/or an intermetallic compound which mainly includes GaGeSbTe. A content ratio of the alloy and/ or the intermetallic compound in the recording layer 3 is preferably 90 atomic percent or higher, and more preferably 96 atomic percent or higher. When the recording layer 3 includes impurities or additives in an amount of 10 atomic percentage or more, it is difficult to be recrystallized at a sufficiently high speed. As a result, the recorded information may not be satisfactorily erased at high scanning speed. Further, when Ga, Ge, Sb, and Te are expressed in a formula of GaxGey(SbzTe1-z)1-x-y wherein x, y, and z each represent an atomic ratio of a positive real number which is less than 1, the alloy or the intermetallic compound is required to satisfy following conditions of:

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

$x + y \leqq 0.1$.

[0012]

A base material of the recording layer of the present invention is a eutectic composition of SbTe, i.e., Sb0.7Te0.3. With the base material, basic properties of the optical information recording medium may be controlled by adjusting the value of z which is a proportion of Sb to Te. By increasing the value of z, the recrystallization rate is increased and the layer is easily crystallized even in a range of high scanning speed. Accordingly, amorphous marks may be erased at high speed, and a direct overwriting operation (namely, an overwriting operation without an erasing operation) may be performed. To achieve the direct overwriting operation at speed of 28.8 m/s to 33.6 m/s corresponding to 24X speed of an operation in a CD, the ratio z is required to be in the above described range, and more preferably at 0.815 or more. On the other hand, an excessively high value of z may remarkably decrease stability of the amorphous marks even though the excessively high value of z may further improve the overwriting properties at high speed. The result is remarkable even when the additive elements to be described below are added to the material. Therefore, the ratio z is required to be below the upper limit for ensuring a storage life of 1000 hours or more at 70 °C. (This finding is clearly distinguished from the finding that the ratio z is optimally from 0.7 to 0.75 in a conventional CD-RW, that is a CD-RW corresponding to 10X speed.)

[0013]

By adding additive elements to SbTe, stability of the amorphous marks may be improved. Practically used materials including a SbTe eutectic mixture, to which an additive element is added, for example include GeInSbTe alloys, to which Ge and In are added, AgInSbTe alloys,

to which Ag and In are added, AgGeInSbTe alloys to which Ag, Ge, and In are added, and the like. However, there is a problem that these materials for the recording layer show markedly decreased storage reliability when the compositional ratio z is set at relatively high to increase the crystallization rate. In other words, these materials show preferable properties in an area in which a recording operation is performed at scanning speed equal to or lower than 14 m/s. However, it is difficult to have the preferable properties in the recording operation at higher scanning speed.

[0014]

Further, in AgInSbTe, GeInSbTe, and AgGeInSbTe materials, a sufficient crystallization rate and storage reliability may be concurrently obtained by increasing an adding amount of In. However, there is a problem that the increased amount of In elevates the crystallization temperature, and it is significantly difficult to initialize the resulting optical information recording medium by using a high power laser beam. When a recording material having such a high crystallization temperature is used, a reflection ratio of the optical information recording medium varies, and reproducing signals with noise components are produced. As a result, a jitter is elevated and an error is increased. Thereby, reliability of the optical information recording medium is decreased.

To solve the problems, use of Ga, which is a congeneric element of In instead of In is effective. Thereby, the recording layer may have a high crystallization rate and may avoid an increased crystallization temperature. Information may be recorded thereon at high scanning speed of 28.8 m/s corresponding to 24X speed in a compact disc (or 33.6 m/s when the basic linear velocity is set at 1.4 m/s), the crystallization temperature may be suppressed to be equal to or lower than 200 °C, thereby recording areas in the recording layer may be easily initialized.

[0015]

From the above description, it is understood that a GaSbTe recording layer is effective for concurrently yielding high speed and easy initialization. However, there is a problem that the GaSbTe recording layer still has low stability of recorded marks. In other words, when recorded amorphous marks are left at 70 °C, the recorded amorphous marks are crystallized and disappear within 1000 hours.

A solution to the problem is addition of Ge. By adding Ge, temperature dependency of the crystallization may be increased. The crystallization rate at a high temperatures of equal to or higher than 200 °C may be increased and the crystallization rate may be decreased at a temperature around 70 °C at the same time. Thereby, the optical information recording medium may have excellent erasing properties at high speed (namely, overwriting properties) and stability of the recording marks, concurrently.

The compositional ratios x and y of Ga and Ge are required to be in the above specified ranges. Further, it is required for the compositional ratios x and y to satisfy a following condition of: $x + y \leqq 0.1$. Excessive adding amounts of Ge and Ga cause high optical absorption of the recording layer. As a result, the optical information recording medium has a remarkably decreased reflection ratio. Thus, reproducing signals have insufficient absolute amplitude, thereby deteriorating reliability of the optical information recording medium.

[0016]

The direct overwriting properties in a recording operation at high speed may be improved by adding trace amounts of elements to the GaGeSbTe recording layer. The amount of such elements is preferably equal to or lower than 10 atomic percent with respect to the amount of GaGeSbTe, and more preferably equal to or lower than 4 atomic percent. By adding trace amounts of Ag, Dy, Mg, Mn, Se, and Sn as the additive elements, the crystallization rate of the recording layer may be finely adjusted. Specifically, the addition of Mn may concurrently increase the crystallization rate and decrease the crystallization temperature

as the effect made by adding Ga. Thereby, the direct overwriting properties are improved at high speed and the initialization (an operation in which the recording layer is crystallized after formation of the recording layer) is easily performed at the same time. The adding amount of Mn is preferably from 1 to 4 atomic percent (from 0.01 to 0.04 in atomic ratio), and more preferably from 1 to 3 atomic percent.

[0017]

The thickness of the recording layer is optimized depending on thermal properties relating to the recording sensitivity, overwriting properties, etc. and optical properties such as a modulation factor, a reflection ratio, etc. An appropriate range of the thickness is from 10 to 25 nm, and more preferably from 12 to 18 nm. A thickness of the recording layer set within the range may provide preferable overwriting properties in a recording operation at high speed of equal to or higher than 20 m/s.

The recording layer may be formed by any arbitrary methods. Among the methods, a vacuum film forming method (gas phase method) is preferred in terms of minimized contamination of impurities and applicability of a film formation on a resin substrate. The vacuum film forming methods include a sputtering method, a vapor deposition method, a CVD (chemical vapor deposition) method, an ion plating method and the like. Among the methods, in terms of productivity, the sputtering method is preferred.

In the sputtering method, an element composition of a target and an element composition of a formed thin film differ little from each other, and a thin film having a desired composition may be easily prepared by using a target material having the desired composition. The target may be an alloy target prepared by mixing and dissolving pure substances of constitutional elements at the desired compositional ratios, or the target may be prepared by sintering fine particles of alloys or such pure substances. In a sintered target, the density of the target is preferably equal to or higher than 90 %,

since a sputtering rate (a thickness of a formed film per unit time) may be increased with increased density of the target.

[0018]

The optical information recording medium of the present invention is required to have a reflective layer on or above the recording layer on opposite side to the substrate. The reflective layer serves to reflect a recording light or a reproducing light which is entered from the substrate. Accordingly, materials having a high reflection ratio are preferably used for the reflective layer. As the materials having the high reflection ratio, Au, Ag, Cu, and Al, as well as alloys or intermetallic compounds which mainly include these metals are preferable. Examples of the materials having the high reflective layer may further include additive elements of metals such as Au, Ag, Cu, Al, Pt, Pd, Ta, Ti, Co, Mn, Mo, Mg, Cr, Si, Sc, Hf and other metals.

The reflective layer also serves to dissipate heat applied in the vicinity of the recording layer in a recording operation and an erasing operation in addition to play an optical role of reflecting a recording or reproducing light beam. To record information at high speed, a material having a high crystallization rate is required to be used for the recording layer as described above. Therefore, it is preferable for the optical information recording medium itself to have a structure for a rapid cooling operation. That is, by using a material having a high thermal conductivity for the reflective layer, marks having a sufficient size may be formed even though the material having the high recrystallization rate is used for the recording layer. Such materials having the high thermal conductivity include Ag or Ag alloys. In Ag alloys, the content of Ag is preferably equal to or higher than 95 % by mole, and more preferably equal to or higher than 99% by mole. The above described metals may be used as an additive element for the alloys. An excessive amount of such an additive element is required to be avoided because the thermal conductivity is decreased by the excessive amount of the additive element. If pure

Ag is used, the purity is preferably equal to or higher than 99.99 % by mole.

The reflective layer is preferably prepared by a vapor film forming method as in a case of preparing the recording layer. The thickness of the reflective layer is set depending on the thermal properties and the optical properties as in the case of setting the thickness of the recording layer. If the reflective layer is excessively thin, the reflective layer may transmit the recording and reproducing light beam, thereby failing to ensure a sufficient reflection ratio. Further, if the reflective layer is excessively thick, the optical information recording medium may have an excessively high heat capacity, thereby decreasing recording sensitivity. Preferably, an optimal thickness determined by the thermal properties and the optical properties is in a range from 800 to 3000 nm, and more preferably in a range from 1000 to 2200 nm.

[0019]

A protection layer is preferably formed on both sides of the recording layer. As shown in Fig. 1, a lower protection layer 2 is provided below the recording layer to protect the substrate, and an upper protection layer 4 is provided above the recording layer to protect the reflective layer.

The lower protection layer is required to protect the resinous substrate from heat generated in and in the vicinity of the recording layer during a recording, erasing, and rewriting (overwriting) operations. Further, the lower protection layer also serves to increase contrast based on the amorphous marks recorded in the recording layer by controlling the optical constant (refractive index) and the thickness of the recording layer.

A material for the lower protection layer preferably has a high refractive index and a high melting point (equal to or higher than 1000 °C). Also, the material is generally a dielectric. The dielectrics include oxides, nitrides, sulfides, halides, and other

compounds of metals, and inorganic substances such as Si, Ge, etc. Further, the substances may be used alone or in combination.

[0020]

Examples of the compounds are oxides, sulfides, and carbides such as Mg, Ca, Sr, Y, La, Ce, Ho, Er, Ti, Zr, Hf, V, Nb, Ta, Zn, Al, Si, Ge, Pb or the like. Examples of the halides are fluorides, etc. of Mg, Ca or Li.

A mixture of ZnS and SiO2 is specifically used as the material for the lower protection layer. The thickness of the lower protection layer is preferably from 40 to 200 nm. The thickness thinner than 40 nm is not preferable because thermal damage to the resinous substrate increases. The thickness thicker than 200 nm is not preferable because mechanical damages such as cracking caused by thermal hysteres of thermal expansion, thermal contraction, etc. occur in repetitive recording operations. Further, the thickness is preferably set in the vicinity of a thickness with which a minimum reflected light may be attained at a reproduction wavelength. Accordingly, the thickness of the lower protection layer is optimally in a range from 50 to 90 nm.

[0021]

The lower protection layer may include a single layer or multiple layers. The lower protection layer includes multiple layers formed with a same material by multiple film forming apparatuses. Thereby, there is an effect that production time and cost of the optical information recording medium are decreased. The optical information recording medium may further include a layer which is adjacent to the recording layer for accelerating the crystallization of the recording layer. Thereby, the initialization margin of the optical information recording medium is ensured. Bi, GaN, etc. are generally used for the layer adjacent to the recording layer for accelerating the crystallization. However, layers including oxides are preferably used in the present invention. Examples of the oxides are Al2O3, SiO2, TiO2, ZrO2, Y2O3, ZnO and other oxides. It is considered that the

oxides have an effect of accelerating the crystallization owing to lattice constants of a crystalline phase, which are relatively near to lattice constants of SbTe materials. The thickness of the oxide layer is appropriately from 1 to 5 nm. If the thickness of the oxide layer is less than 1 nm, a uniform film may not be formed, thereby inducing nonuniformity in the optical disc. Further, a sputtering rate for the above described oxide layer is one fifth or less than one fifth of the sputtering rate of the materials for a general protection layer such as ZnS, etc. Accordingly, the thickness of the oxide layer is preferably set at the least possible thickness at which crystallization is accelerated effectively.

To include multiple layers in the lower protection layer, the total thickness of the protection layers is preferably within the above specified range, and proportion among the protection layers may be set depending on optical properties, thermal properties, productivity and the like.

[0022]

The upper protection layer serves as an interlayer for preventing diffusion of the materials for the recording layer and the reflective layer into each other and as a role to control the thermal properties. The materials for the upper protection layer may be the materials for the lower protection layer. But materials having low thermal conductivity are preferable. If the upper protection layer includes a material having high thermal conductivity, the resulting layer may have decreased thermal efficiency. Therefore, when a focused beam is applied, a volume of the recording layer material, with which a temperature equal to or higher than its melting point may be reached, decreases. Thus, sensitivity of the optical information recording medium remarkably decreases and sizes of recording marks decreases concurrently. Thereby, the optical information recording medium fails to ensure a sufficient amplitude of reproducing signals.

[0023]

The thickness of the upper protection layer is preferably in a range from 5 to 50 nm, and more preferably in a range from 10 to 23 nm. Also, the upper protection layer may include multiple layers.

Specifically when a sulfide and a halide are used for the upper protection layer and Ag or an alloy which mainly includes Ag, is used for the reflective layer, the reflective layer apt to corrode, and the storage reliability of the recording medium is decreased. In such a case, it is preferred that the upper protection layer includes multiple layers having a layer adjacent to the reflective layer, which is made of a material having low corrosion to Ag. Examples of such materials are Si, SiO2, SiC, GeN, GaN and the like. The thickness of such a layer is preferably in a range from 2 to 10 nm, and more preferably in a range from 2 to 5 nm so as to maintain a reflection ratio of the optical information recording medium. If the thickness of the optical information recording medium is less than 2 nm, the optical information recording medium may not serve a roll of preventing corrosion. Therefore, the thickness less than 2 nm is not preferable.

In addition, an interlayer made of a material for accelerating the crystallization of the recording layer material may be provided adjacent to the recording layer, as in the lower protection layer.

[0024]

The optical information recording medium may further include an overcoat layer 6 as shown in Fig. 1 for protecting the multiple layers provided on the substrate from physical and chemical damages. The overcoat layer 6 generally includes a material made of a resin and is preferably prepared by applying and curing an ultraviolet-curable resin, an electron beam curable resin, a thermosetting resin or the like. Among such materials made of resin, the ultraviolet-curable resin is preferred for reducing a damage to the optical information recording medium during film formation. The overcoat layer may be prepared by using a dipping method, a spin coating method, etc. The spin coating method is preferred in terms of uniformity in thickness. When the reflective layer uses materials

which includes Ag or a material mainly including Ag, a material which is not corrosive to Ag is preferably used for the overcoat layer.

The recording medium may further include a multilayer film on the overcoat layer to further protect the optical disc from physical and chemical damages.

[0025]

When the recording layer of the optical information recording medium prepared as described above is amorphous, the optical information recording medium is required to undergo initialization, in which recording areas are crystallized. The optical information recording medium may be initialized by any methods, such as a method in which the recording layer is irradiated and scanned with a high power laser beam and is thereby crystallized, a flash method in which the entire optical information recording medium is irradiated with light, and other methods, for example.

The method using a high power laser beam is preferred because the irradiation energy of the laser beam may be converged to the vicinity of the recording layer by using an objective lens. In addition, the use of the high power laser beam may increase a diameter of an irradiation beam in the vicinity of the recording layer and may increase the scanning speed. The power of the high power laser beam in terms of power consumption is preferably equal to or higher than 500 mW, and more preferably equal to or higher than 900 mW. Further, it is not preferable to have the laser beam in an oblong shape, which has a longer side in a direction perpendicular to the scanning direction since an area which is initialized in one scanning operation is large. The laser beam preferably has a length in the scanning direction from 0.5 to 2.0 μm and a width in a direction perpendicular to the scanning direction from 50 to 300 μm. The scanning speed of the beam varies depending on the width and power of the laser beam. The scanning speed may be increased as energy of a laser beam is increased per unit area (that is, as the diameter is decreased and as the power of the beam is increased, the scanning speed may be

increased). The scanning speed is preferably in a range from 1.0 to 12.0 m/s. When a laser beam with output power of 900 mW is used, the scanning speed in a range from 1.0 to 2.5 m/s is optimal.

[0026]

Information is recorded, erased, reproduced, and/or rewritten on the optical information recording medium of the present invention by irradiating and scanning the vicinity of the recording layer of the optical information recording medium with focused light. A laser beam is used for recording and reproducing operations. A wavelength of the laser beam may be selected depending on the recording density, etc. For example, the wavelength may be 780 nm in a CD and 650 nm or 660 nm in a DVD. The numerical aperture NA of the objective lens for focusing the light beam is selected depending on the wavelength of the laser beam and the recording density. For example, a NA may be 0.50 in a CD-R/RW, 0.55 in a DD (double density) CD-RW, 0.65 in a DVD+R/RW, etc.

Information to be recorded on the optical information recording medium of the present invention is modulated by a mark interval modulation method and a mark length modulation method which are an application of PWM (pulse width modulation) to an optical disc medium. Then, the information is recorded on the optical information recording medium. Eight to fourteen modulation (EFM) used in compact discs and EFM+, etc., which are one type of eight to sixteen modulation methods used in DVD are used as examples of the modulation methods.

[0027]

Information is recorded on the optical information recording medium by applying a light beam in which intensity is modulated. A technique disclosed in Japanese Patent Application Laid-open (JP-A) No. 09-219021 or a technique described in "Orange Book Part III" are examples of using the intensity modulation. In the latter technique, the irradiation power is modulated in three values. An example of the technique is shown in Figs. 2. Fig. 2(a) schematically shows an amorphous mark to be recorded. Fig. 2(a) shows the amorphous mark

using EFM (eight to fourteen modulation) as an example, and the mark length relative to a reference clock period of Tw is 3Tw, 4Tw, ... 11Tw. When the mark length is defined as nTw wherein n is 3, 4, ...11, the irradiation pattern for use in a recording operation (hereinafter, referred to as "recording strategy") is as shown in Fig. 2(b). With reference to Fig. 2(b), the irradiation power is modulated into three values of Pw > Pe > Pb, and the number of pulses with power P of Pw is n-1.

The parameters of the recording method are represented by Ttop, dTtop, Tmp, and dTera.

[0028]

In the recording method, there is the case where a response time of the laser beam does not catch up with an interval, i.e., a pulse width in a high speed recording operation in which the reference clock period in a recording operation becomes short. At speed corresponding to 24X speed in a CD, the reference clock period is 9.6 ns, and the clock frequency is 104 MHz. In this case, rise and fall times of emission of the laser beam is required be equal to or lower than 1 ns for applying sufficient energy to the CD.

To record information at high speed by using a laser beam having long rise and fall times, there is a method in which number of the pulses is reduced as disclosed in U.S. Patent No. 5,732,062. In other words, in a case where m pulses are used for the formation of nTw marks, a relation of $n = 2m$ is satisfied when n is an even number, and a relation of $n = 2m + 1$ is satisfied when n is an odd number. By using the recording strategy, information may be recorded at speed corresponding to 24X speed even though a laser beam has rise and fall times as much as 2 ns.

An example of the strategy is show in Fig. 3, which is in EFM as shown in Figs. 2.

[0029]

Information is recorded on the optical information recording medium of the present invention in a range of scanning speed from 9.6

to 33.6 m/s and in a range of a reference clock period from 9.6 to 29.0 ns during a recording operation. The information of the scanning speed during the recording operation is preferably preformatted on the optical information recording medium. That is, the information regarding the range of the scanning speed, in which a recording operation may be performed, is preferably added to the optical information recording medium before the information is recorded thereon.

The information about scanning speed may be preformatted by any method such as a method in which the information is preformatted on the substrate itself. The information is preformatted on the substrate for example by a technique of forming emboss pits on the substrate or a technique of inputting the information to the wobbling of the groove on the substrate. Also, there is a method in which the information is recorded on a part of the optimal information recording medium by using a recording apparatus. Among these methods, the method of preformatting the information on the substrate is preferable in terms of production of the optimal information recording medium. In the technique of forming the emboss pits, the emboss pits and the groove have different optimum depths, thereby inviting problems in processing the substrate or stamping for the formation of the substrate. Accordingly, the technique of preformatting the information into the wobbling of the groove is most preferable.

[0030]

As such an example, there is a method of preformatting the information about scanning speed or appropriate recording conditions instead of the address information according to a similar method of the method of ATIP or ADIP. Examples of the preformatting information about scanning speed in ATIP are HTS (highest testing speed) and LTS (lowest testing speed) in a CD-R and a CD-RW. Examples of preformatting information using ADIP are maximum recording velocity and reference recording velocity in a DVD+R. A recording apparatus reads out the information about scanning speed, at which a recording

operation may be performed, from the optical information recording medium. Thereby, appropriate recording scanning speed may be set.

The information about scanning speed may be written on the optical information recording medium in a format which uniquely determines the information. A multiple of the reference scanning speed is preformatted in a CD-R and a CD-RW, which are preformatted in ATIP. In this case, the scanning speed may be determined based on the information regarding a preformatting operation since the reference scanning speed in a CD is defined at 1.2 to 1.4 m/s. For example, the scanning speed is 28.8 to 33.6 m/s when the preformatted multiple of the scanning speed is 24X.

The aforementioned speed range is required to include a range at which a recording operation may be performed according both to the recording strategy in which $m = n - 1$ and the recording strategy in which $n = 2m$ (or $n = 2m - 1$). Performances of the recording operation according to the recording strategy in which $m = n - 1$ (i.e., $n = m + 1$) is preferably limited to a range of relatively low recording speed, and the recording operation is more preferably performed at speed corresponding to speed equal to or lower than 16X speed in a CD, namely at scanning speed equal to or lower than 22.4 m/s and a reference clock period Tw of equal to or lower than 14.4 ns.

[0031]

[Embodiment]

Hereinafter, the present invention is described further in detail with reference to examples and comparative examples. However, the present invention is not limited to the examples.

[0032]

Example 1

A disc is prepared by sequentially forming a lower protection layer, a recording layer, an upper protection layer, a reflective layer, and an overcoat layer on a polycarbonate transparent substrate having a transferred spiral continuous groove.

The used substrate is a substrate for a CD-RW having an outer diameter of 120 mm and a thickness of 1.2 mm. The substrate has been prepared by an injection molding method and has the spiral continuous groove transferred by using a stamper. The groove transferred on the substrate is observed by an AFM (atomic force microscope) and is found to have a groove width of 620 nm and a groove depth of 40 nm. The groove is wobbled so that an average frequency of the wobbling is 22.05 kHz when scanning at linear velocity of 1.2 m/s. Further, address information is preformatted on the wobbling by frequency modulation. The modulation method and the address information are in conformity with the international standard specifications on CD-RW, which is called "Orange Book" Recordable Compact Disc Systems Part III, Volume 2, Version 1.1.

To ensure the recording and reproducing reliability of the resulting optical information recording medium, birefringence of the substrate is controlled so as to be equal to or lower than 40 nm at a recording/reproducing wavelength of 780 nm. The birefringence is optimized by controlling the injection speed of a resin and the temperature of a mold when performing an injection molding operation.

Further, the substrate is annealed at 60 °C for 12 hours before formation of other layers to be described below, thereby sufficiently removing adsorbed or taken-in moisture from the substrate.

The lower protection layer including a mixture of ZnS and SiO2 is formed on the transparent substrate. The molar ratio of ZnS to SiO2 is 80:20. The lower protection layer is formed by a RF magnetron sputtering method, which is a kind of a vacuum film forming method. A process uses general inert Ar gas as sputtering gas at power of a high voltage power source of 4 kW and an inflow of Ar gas of 15 sccm. The formed lower protection layer has a thickness of 75 nm.

On the lower protection layer, the recording layer including a material represented by the following compositional formula is formed:

$$Ga_xGe_y(Sb_zTe_{1-z})_{1-x-y}$$

wherein x, y, and z are atomic ratios listed below:

X = 0.038;

Y = 0.030; and

Z = 0.815.

The recording layer is formed by a DC magnetron sputtering method by using the GaGeSbTe alloy target. Ar gas is used as a sputtering gas at an inflow of 20 sccm and a sputtering power of 400 W is set. The formed recording layer has a thickness of 16 nm.

The upper protection layer is further formed on the recording layer using the same material as the material of the lower protection layer. Similarly, the upper protection layer is also formed by a RF magnetron sputtering method by using Ar gas. The sputtering power is set at 1.5 kW and the film thickness is set at 18 nm.

A film of Si is formed to have a thickness of 4 nm on the upper protection layer for preventing sulfuration of Ag. The material of Si having purity of 99.99 % is used. The Si film is formed by a DC magnetron sputtering method as the formation of the recording layer. The sputtering power at the time of the Si film formation is set at 0.5 kW.

An Ag reflective layer is formed on the Si layer. The formation is performed by a DC magnetron sputtering method by using a target having purity equal to or higher than 99.99 %. The DC magnetron sputtering method is performed at an inflow of Ar gas into a sputtering chamber in an amount of 20 sccm and sputtering power of 3 kW. The Ag reflective layer is formed to have a thickness of 140 nm.

The thicknesses of the above prepared five thin films are optically measured values by using a spectro-ellipsometer. Further, the thin films are formed by using a sheet-fed sputtering apparatus. The sheet-fed sputtering apparatus is set in a way that the thin film layers are not exposed to the air while forming the lower protection layer to the reflective layer for preventing chemical reactions such as oxidation, etc. of the recording layer or adsorption of gas.

The overcoat layer is formed on the reflective layer by using a commercially available coating material for optical discs (an UV curable resin SD 318 available from Dainippon Ink and Chemicals, Inc., Japan). A film of the coating material is applied by a spin coating method and is cured by being irradiated by an UV lamp. The formed overcoat layer has a thickness of 8 μm in an inner circumference of the optical disc and a thickness of 14 μm in an outer circumference of the optical disc.

[0033]

The recording layer of the completed optical disc is in a rapid cooling condition after a sputtering operation and is entirely in an amorphous phase. The recording layer is therefore initialized by being irradiated and scanned with a high power laser beam. The high power laser beam at power of 900 mW is used. The objective lens of the laser is adjusted so that the laser beam is focused in the vicinity of the recording layer of the optical disk and is to be elliptical. The elliptically focused beam has a minor axis in agreement with the scanning direction (that is, the circumferential direction of the disc). In other words, the objective lens of the laser is adjusted so that the minor axis and the circumferential direction of the elliptically focused beam coincide. The beam has the minor axis of 1 μm and a major axis of 90 μm when the edge of the beam is defined as a position where the beam has intensity of 1/e2 times as much as the peak intensity, wherein e is the base of natural logarithms. The entire optical disc is initialized by being spirally scanned with the laser beam at scanning speed of 2 m/s. At this time, the pitch of spiral (shift in a radius direction per rotation) is set at 45 μm so that one area is scanned twice with the laser beam.

The initialized optical disc is an unrecorded CD-RW satisfying mechanical properties and unrecorded signal properties which are described in Orange Book Part III.

Information is recorded and overwritten on the completed optical disc, and recording signal properties are evaluated. The

evaluation of signal properties is performed by using an optical disc tester DDU-1000 (available from Pulstec Industrial Co., Ltd.). The optical pickup of the tester has a NA of 0.50, λ of 789 nm, and maximum emission power of 35 mW. In the optical disc tester, number of revolutions of an optical disc may be up to 6000 rpm, corresponding to 30X speed in a compact disc.

A recording strategy shown in Fig. 4 is used, in which a pulse emission period is set at nT/m wherein m is the number of pulses, and nT is the reference clock period of a mark to be recorded.

Respective parameters of the recording strategy are set as follows. The symbol "T" in the figure has the same meaning as Tw.

Tmp = 1.0T

Tmp' = 1.6T

Td1 = 0.5T

Td2 = 0T

δ = 0.125T

Scanning speed: 28.8 m/s (corresponding to 24X speed in a CD)

Reference clock period T = 9.64 ns

Further, the recording powers Pw, Pe, and Pb are set as follows.

Pw = 33 mW

Pe = 11 mW

Pb = 0.5 mW

A pattern in conformity with a rule in EFM is recorded as information to be recorded. Further, the recording procedure includes a direct overwriting operation repeated up to a total of 1000 times.

The optical disc tester is set to have scanning speed of 1.2 m/s corresponding to 1X speed in a CD for evaluating the recording signals. The evaluation is made for an 11T modulation factor, a 3T mark jitter, and a 3T space jitter. These parameters are specified in the standard specification of CD-RW as follows.

11T modulation factor: 0.55 to 0.70

Jitter: equal to or lower than 35 ns

The results of the measurement on the prepared optical disc are shown in Fig. 5. As can be understood by referring to Fig. 5, the optical disc yields preferable results satisfying the standard specification in 1 to 1000 repetitive recording cycles.

[0034]

The pattern is recorded and the signal properties of the same optical disc subjected to the above described evaluation are determined by the above procedure except that the respective parameters of the recording strategies and the recording powers of Pw, Pe, and Pb are changed as follows:

Tmp = 0.5T;

Tmp' = 0.8T;

Td1 = 0.5T;

Td2 = 0T;

δ = 0.125T;

Scanning speed: 9.6 m/s (corresponding to 8X speed in a CD);

Reference clock period T: 28.9 ns;

Pw = 30 mW;

Pe = 10 mW; and

Pb = 0.5 mW.

The results of the measurement are shown in Fig. 6. As can be understood by referring to Fig. 6, the optical disc yields preferable results satisfying the standard specification in the 1 to 1000 repetitive recording cycles.

Further, the above used optical disc is left at 80 °C and relative humidity of 85 % for 300 hours, and the 3T jitter in a record part is measured. As a result, the 3T jitter is found to be equal to or lower than 35 ns, indicating that the optical disc has sufficient storage reliability.

As can be understood from the above described results, a CD-RW capable of performing a direct overwriting operation at 8X to 24X speed corresponding to a CD and having sufficient storage reliability may be provided.

[0035]

Comparative Example 1

An optical disc is prepared and is initialized by the same procedure as the procedure of the example 1 except that a material for the recording layer has following compositions:

X = 0.029;

Y = 0.039; and

Z = 0.820.

However, the optical disc invited noise on reproducing signals before a recording operation. In addition, a pattern is recorded on the optical disc by the procedure used in the example 1 which is performed at scanning speed of 28.8 m/s and the properties are evaluated. As a result, the jitter in the first recording cycle exceeds 35 ns, which is out of the specification. Since the adding amount of Ge exceeds the adding amount of Ga ($x < y$), it is considered that a crystallization temperature is high and a uniformly crystallized phase may not be produced.

[0036]

Comparative Example 2

An optical disc is prepared by the same procedure as the procedure used in the example 1 except that the composition of materials of the recording layer is changed as follows:

X = 0.016;

Y = 0.049; and

Z = 0.793.

Further, the prepared optical disc is initialized by the procedure used in the example 1 except that the scanning speed is set at 4.0 m/s.

A pattern is recorded on the optical disc and the signal properties are determined by the procedure used in the example 1 except that the respective parameters of the recording strategies and the recording powers Pw, Pe, and Pb are changed as follows:

Tmp = 1.0T;

Tmp' = 1.6T;

Td1 = 0.5T;

Td2 = 0T;

δ = 0.125T;

Scanning speed: 28.8 m/s (corresponding to 24X speed in a CD);

Reference clock period T = 9.64 ns;

Pw = 30 mW;

Pe = 10 mW; and

Pb = 0.5 mW.

As a result, in the first recording cycle, the optical disc has preferable results of a 3T space jitter of 20 ns and a 3T mark jitter of 19 ns. However, in the second recording (overwriting) cycle, the optical disc shows a space jitter and a mark jitter of about 42 ns, respectively. Accordingly, it is confirmed that information may not be overwritten on the optical disc at the speed corresponding to 24X speed in a CD.

[0037]

Example 2

An optical disc is prepared by the procedure used in the example 1 except that the composition of the materials of the recording layer is changed to a composition having a following compositional formula of:

$[Ga_xGe_y(Sb_zTe_{1-z})_{1-x-y}]_{1-w}Mn_w$

Wherein

X = 0.038,

Y = 0.030,

Z = 0.815, and

W = 0.02.

In addition, the prepared optical disc is initialized by the procedure used in the example 1 except that the scanning speed is set at 2.5 m/s.

A pattern is recorded on the initialized optical disc, and the signal properties are evaluated by the procedure used in the example

1. Figs. 7 and 8 show the results at a scanning speed of 28.8 m/s and at a scanning speed of 9.6 m/s, respectively. As shown in Figs. 7 and 8, the optical disc has preferable results at both speeds, indicating that the addition of Mn to the recording layer ensures preferable properties in a recording operation performed at higher scanning speed.

[0038]

Example 3

An optical disc is prepared by the procedure used in the example 1 except that an oxide layer including ZrO_2 (77% by mole), TiO_2 (20% by mole), and Y_2O_3 (3% by mole) is formed between the lower protection layer and the recording layer. The oxide layer is formed by the RF magnetron sputtering method which is also used to form the lower protection layer.

The prepared optical disc is initialized by the procedure used in the example 1 except that the scanning speed is set at 2.5 m/s. Noise on reproducing signals of the optical disc before a recording operation is checked. As a result, it is found that the noise is substantially equal to the noise of the optical disc according to the example 1. In addition, a pattern is recorded on the optical disc by the procedure used in the example 1 at scanning speed of 28.8 m/s, and the signal properties are evaluated. As a result, the optical disc has a preferable result that a jitter in the first recording operation is 23 ns.

Accordingly, the results verify that the scanning speed during the initialization may be increased by forming an oxide layer adjacent to the recording layer.

[0039]

Comparative Example 3

An optical disc is prepared by the procedure used in the example 1 except that the composition of the materials for the recording layer is changed as follows:

$X = 0.072$;

Y = 0.029; and

Z = 0.790 (x + y = 0.11).

The prepared optical disc is initialized by the procedure used in the example 1 except that the scanning speed is set at 2.0 m/s. The initialized optical disc has a low reflection ratio of 0.14 before a recording operation and does not satisfy the standard specification of from 0.15 to 0.25.

Further, a pattern is recorded on the optical disc by the procedure used in the example 1 at scanning speed of 28.8 m/s and the signal properties are evaluated. In the case, the jitter in the second recording cycle exceeds 50 ns, showing that the optical disc may not have satisfactory properties.

The satisfactory properties may not be obtained probably because a value of x + y exceeds 0.1, and the recording layer thereby has an excessively high absorption coefficient and has a decreased reflection ratio. As a result, the optical disc may not have satisfactory overwriting jitter.

[0040]

Comparative Example 4

An optical disc is prepared and initialized by the procedure used in the example 1 except that the composition of the materials for the recording layer is changed as follows:

X = 0.048;

Y = 0.031; and

Z = 0.863.

A pattern is recorded on the optical disc by procedure used in the example 1 at scanning speed of 28.8 m/s and the signal properties are evaluated. As a result, the optical disc has an 11T modulation factor of 0. 42, showing that the optical disc may not have a sufficient reproducing signal amplitude.

[0041]

Example 4

An optical disc is prepared by the procedure used in the example 1 except that the initialization conditions are set as follows:

Initialization power: 900 mW;

Scanning speed: 3.0 m/s; and

Shift in radius direction per one rotation: 20 μm.

A pattern is recorded on the optical disc by the procedure used in the example 1 at scanning speed of 28.8 m/s and the signal properties of the optical disc are evaluated. As a result, a preferable result of the jitter of 30 ns is obtained after 10 times of overwriting cycles. On the other hand, noise due to the fine structure of crystals occurs in reproducing signals before a recording operation. Thereby, the jitter of the optical disc in the first recording cycle is 32 ns, which is higher than the jitter in the optical discs according to the examples 1 to 3.

[0042]

Comparative Example 5

An optical disc is prepared by the procedure used in the example 1 except that InGeSbTe having the following compositional formula is used as the material for the recording layer (Ga is replaced with In):

InxGey(SbzTe1-z)1-x-y

Wherein x, y, and z are atomic ratios and the values are as follows:

X = 0.035;

Y = 0.02; and

Z = 0.802.

A pattern is recorded on the above-prepared optical disc once by the procedure used in the example 1, and the recorded optical disc is then kept at a temperature of 80 °C and relative humidity of 85 % for 300 hours. As a result, the optical disc shows a jitter of 23 ns before the environmental test but a markedly deteriorated jitter of 42 ns after the test.

The same optical disc is subjected to two recording cycles (i.e., one overwrite procedure) by the procedure used in the example 1 at

scanning speed of 28.8 m/s. As a result, a jitter is 45 ns, which is significantly out of the specification.

These results show that the use of In instead of Ga fails to ensure storage reliability and overwriting properties.

[0043]

[Effects of the Invention]

According to inventions 1 and 2, a preferable direct overwriting operation may be performed at scanning speed in a range from 9.6 to 33.6 m/s which corresponds to 8X to 24X speed in a CD-RW, and the recorded information may have a satisfactory storage life.

According to invention 3, a crystallization temperature of a material of a recording layer may be decreased, and the recording layer may be easily crystallized by a high power laser beam. Thus, reproducing signals with low noise (high signal-to-noise ratio) and a uniform reflection ratio may be obtained.

According to invention 4, information may be recorded, erased and/or rewritten at appropriate scanning speed.

According to invention 5, the recording layer may be rapidly cooled easily due to increase in thermal conductivity of the reflective layer when recording and/or rewriting information. The recording layer may be thereby converted into an amorphous phase even when sufficient energy is not applied to the optical information recording medium in a recording operation at high scanning speed equal to or higher than 20 m/s. Thus, the optical information recording medium may have preferable recording sensitivity even in a high speed recording operation.

According to invention 6, by arranging an oxide film adjacent to the recording layer, the crystallization of the recording layer may be further accelerated. Thereby, through invention 6 the same effect as the effect of the invention 3 may be received.

According to inventions 7 to 11, the scanning speed of a high power laser beam in an initialization process of the optical information recording medium is optimized, and sufficient energy may

be applied to the material for the recording layer so as to cause the material of the recording layer to be more uniformed with little optical anisotropy. Thereby, noise in the reproducing signals may be reduced.

According to inventions 8 to 10, the present invention provides a sputtering target for the formation of the recording layer of the optical information recording medium of the present invention.

According to inventions 12 and 13, an appropriate recording method of the optical information recording medium of the present invention may be provided.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a sectional view (schematic diagram) showing an example of an optical information recording medium according to the present invention.

[Fig. 2]

Figs. 2 are drawings showing an example of a technique of applying light with modulated intensity, in which Fig. 2(a) schematically shows an example of an amorphous mark to be recorded, and Fig. 2(b) shows an irradiation pattern (recording strategy) for use in a recording operation.

[Fig. 3]

Fig. 3 is a drawing showing an example of a strategy for reducing number of pulses.

[Fig. 4]

Fig. 4 is a drawing showing a recording strategy used in evaluation of recording signal properties of an optical disc according to example 1.

[Fig. 5]

Fig. 5 is a drawing showing a result of a measurement made on the optical disc of example 1 at scanning speed of 28.8 m/s.

[Fig. 6]

Fig. 6 is a drawing showing a result of a measurement made on the optical disc of example 1 at scanning speed of 9.6 m/s.

[Fig. 7]

Fig. 7 is a drawing showing a result of a measurement made on the optical disc of example 2 at scanning speed of 28.8 m/s.

[Fig. 8]

Fig. 8 is a drawing showing a result of a measurement made on the optical disc of example 2 at scanning speed of 9.6 m/s.

[Reference Numerals]

Tw: Reference clock period

3Tw~11Tw: Mark length

Pw: Recording power

Pe: Erase power

Pb: Bias power

Ttop: Width of top pulse

Dtop: Starting time of top pulse

Tmp: Width of peak power pulse of multi pulse portion

Dtera: Starting time of erasing operation

T: Reference clock signal

Tmp': Width of peak pulse when n = 3

Td1: Period of time between data rise time and first peak pulse rise time

Td2: Period of time between time being at a position where P = Pe and data fall time

Td2': Td2 when n = 3

δT: Extension of last pulse when n is an odd number (with respect to Tmp)

[Name of Document] Figure

[Name of Document] Abstract of the Disclosure

[Abstract]

[Objective of the Invention]

To provide an optical information recording medium (particularly, a CD-RW) capable of performing a direct overwriting operation at high speed and a recording method of the optical information recording medium.

[Means for Achieving the Objectives]

In an optical information recording medium at least including a recording layer and a reflective layer which are disposed on a transparent substrate, wherein the optical information recording medium records, erases and/or rewrites information by irradiating and scanning the recording layer with focused light to form and erase recording marks on the recording layer, the optical information recording medium is characterized by including an alloy or an intermetallic compound represented by a following formula, which mainly includes Ga, Ge, Sb, and Te in the recording layer:

GaxGey(SbzTe1-z)1-x-y

wherein x, y, and z represent an atomic ratio of a positive real number which is less than 1 and satisfy following conditions of;

$0.02 \leqq x \leqq 0.06$;

$0.01 \leqq y \leqq 0.06$;

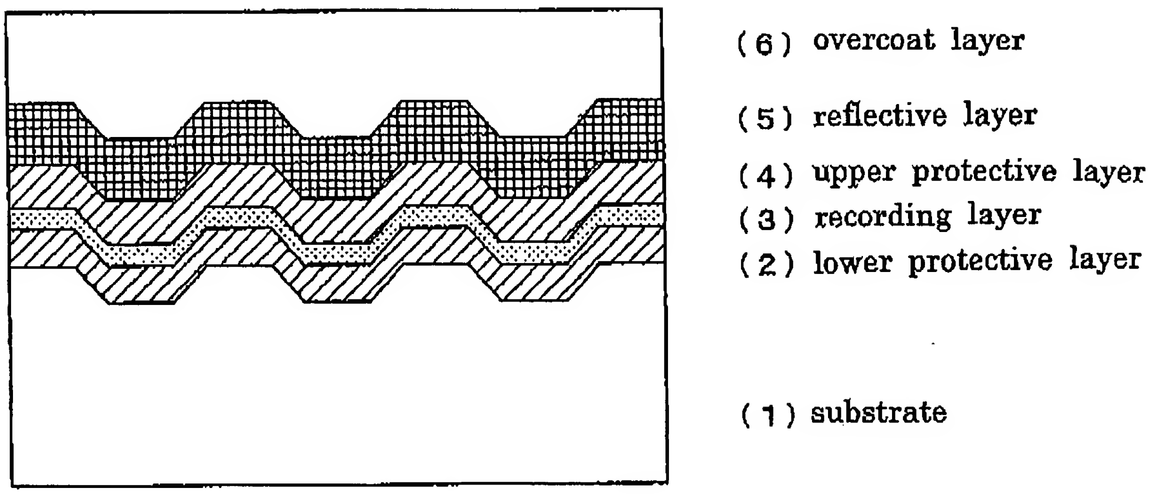
$0.80 \leqq z \leqq 0.86$;

$x \geqq y$; and

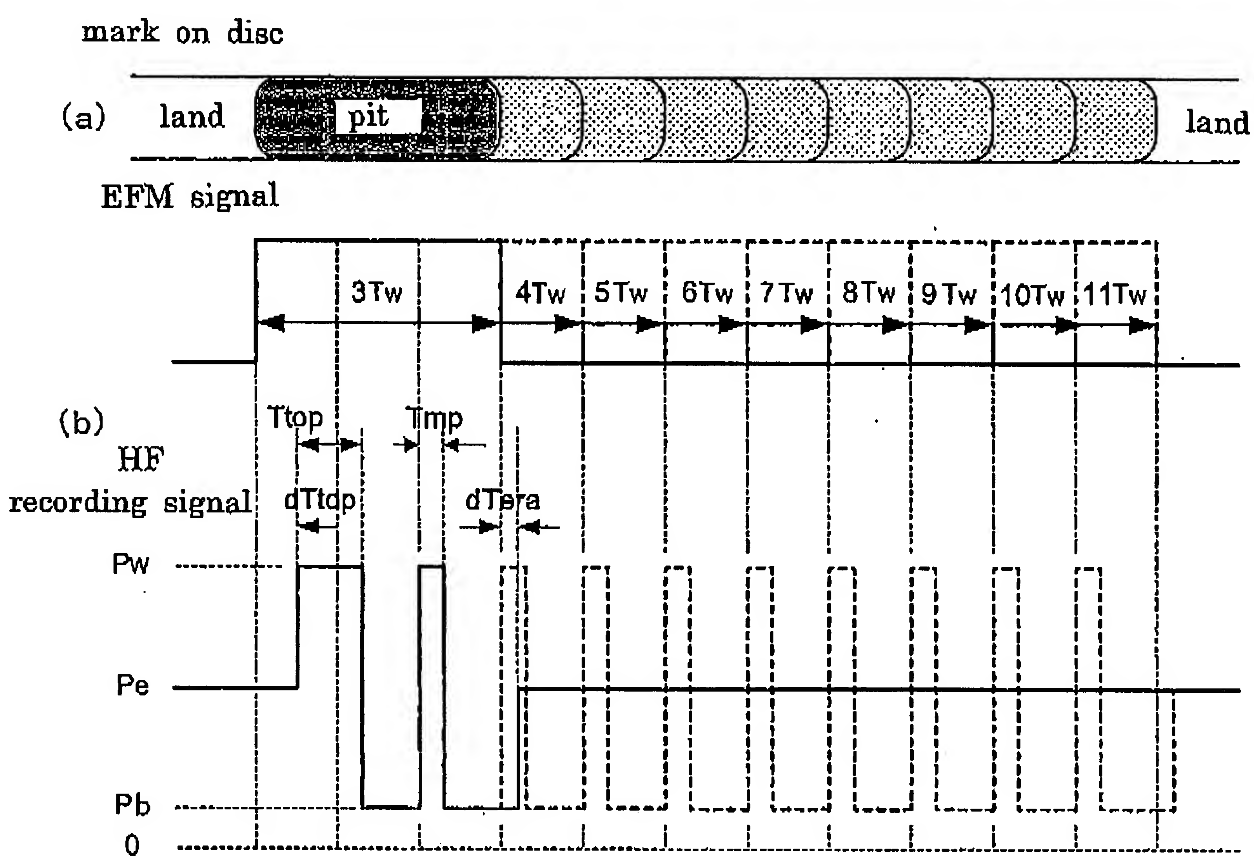
$x + y \leqq 0.1$.

[Selected Drawing] Fig. 1

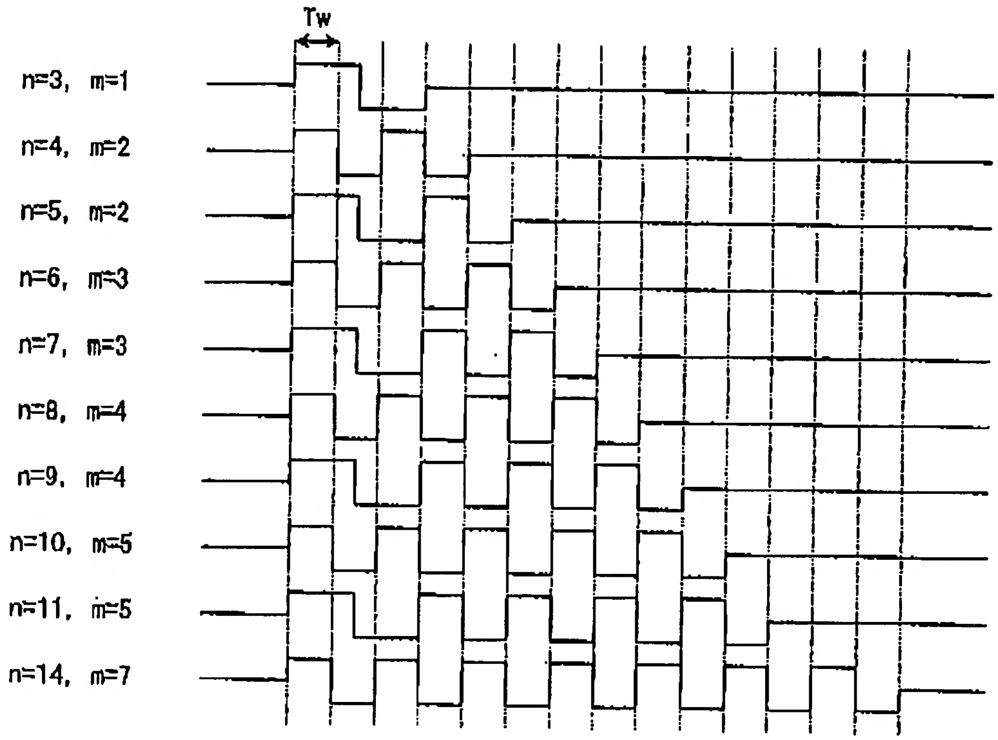
〔FIG. 1〕


(6) overcoat layer
(5) reflective layer
(4) upper protective layer
(3) recording layer
(2) lower protective layer
(1) substrate

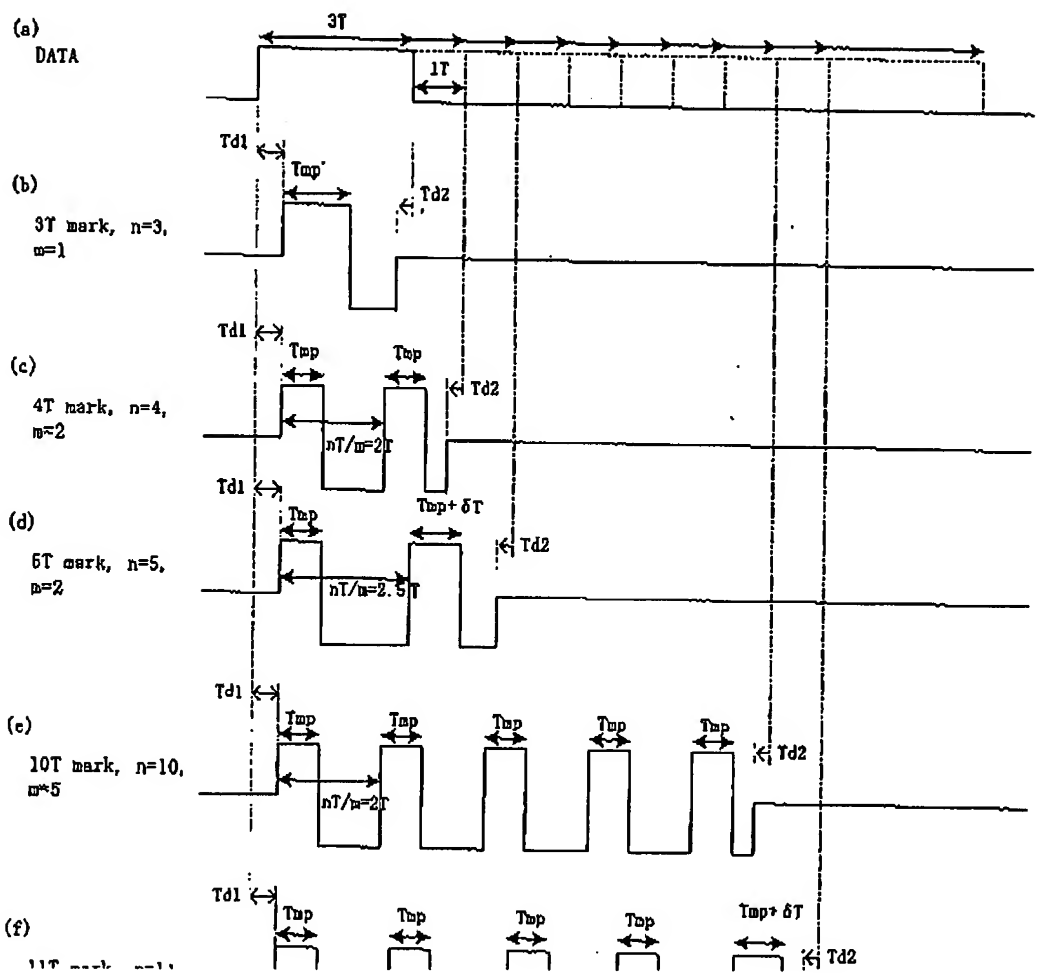
〔FIG. 2〕


mark on disc
(a)
land
pit
land
EFM signal
3Tw
4Tw
5Tw
6Tw
7Tw
8Tw
9Tw
10Tw
11Tw
(b)
HF
recording signal
Ttop
Tmp
dTtop
dTera
Pw
Pe
Pb
0

〔FIG. 3〕

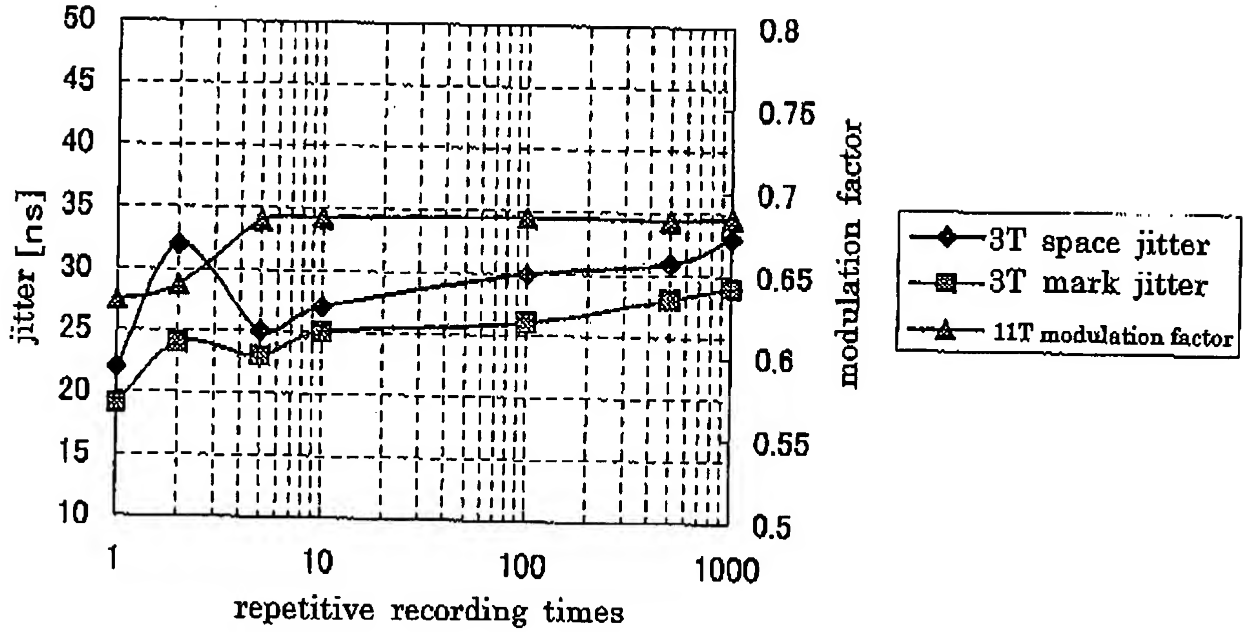

Tw
n=3, m=1
n=4, m=2
n=5, m=2
n=6, m=3
n=7, m=3
n=8, m=4
n=9, m=4
n=10, m=5
n=11, m=5
n=14, m=7

〔FIG. 4〕


(a)
DATA
3T
1T
Td1
(b)
Tmp'
Td2
3T mark, n=3,
m=1
Td1
(c)
Tmp
Tmp
Td2
4T mark, n=4,
m=2
nT/m=2T
Td1
(d)
Tmp
Tmp+ δT
Td2
5T mark, n=5,
m=2
nT/m=2.5T
Td1
(e)
Tmp
Tmp
Tmp
Tmp
Tmp
Td2
10T mark, n=10,
m=5
nT/m=2T
Td1
(f)
Tmp
Tmp
Tmp
Tmp
Tmp+ δT
Td2

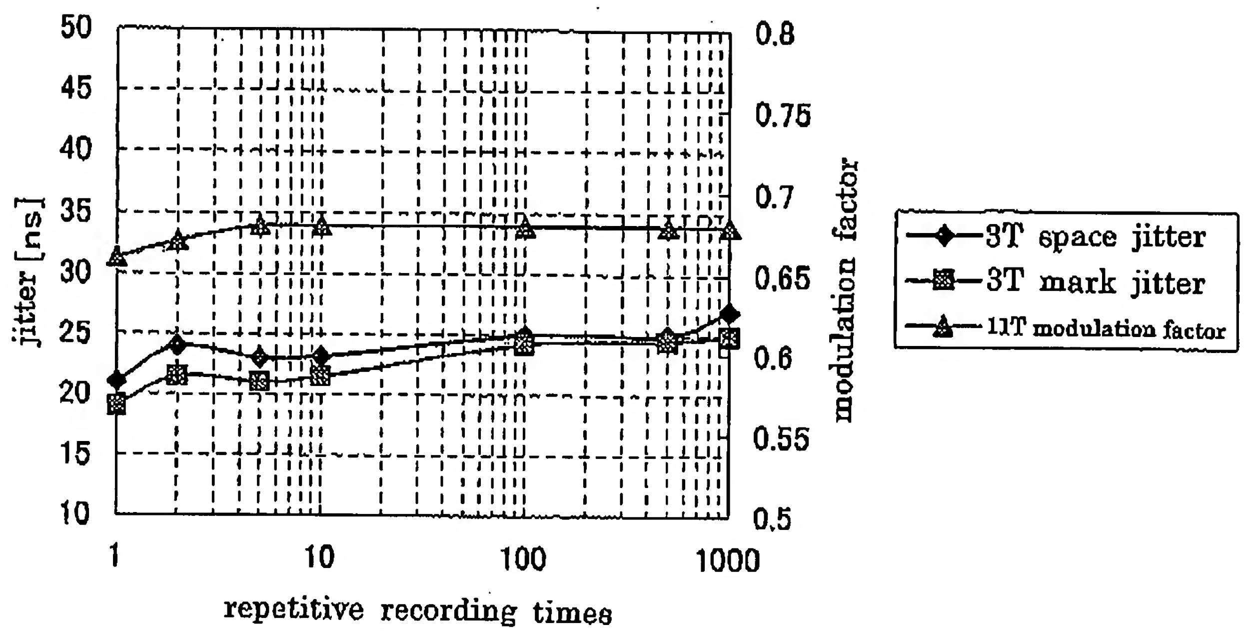
[FIG. 5]

Example 1

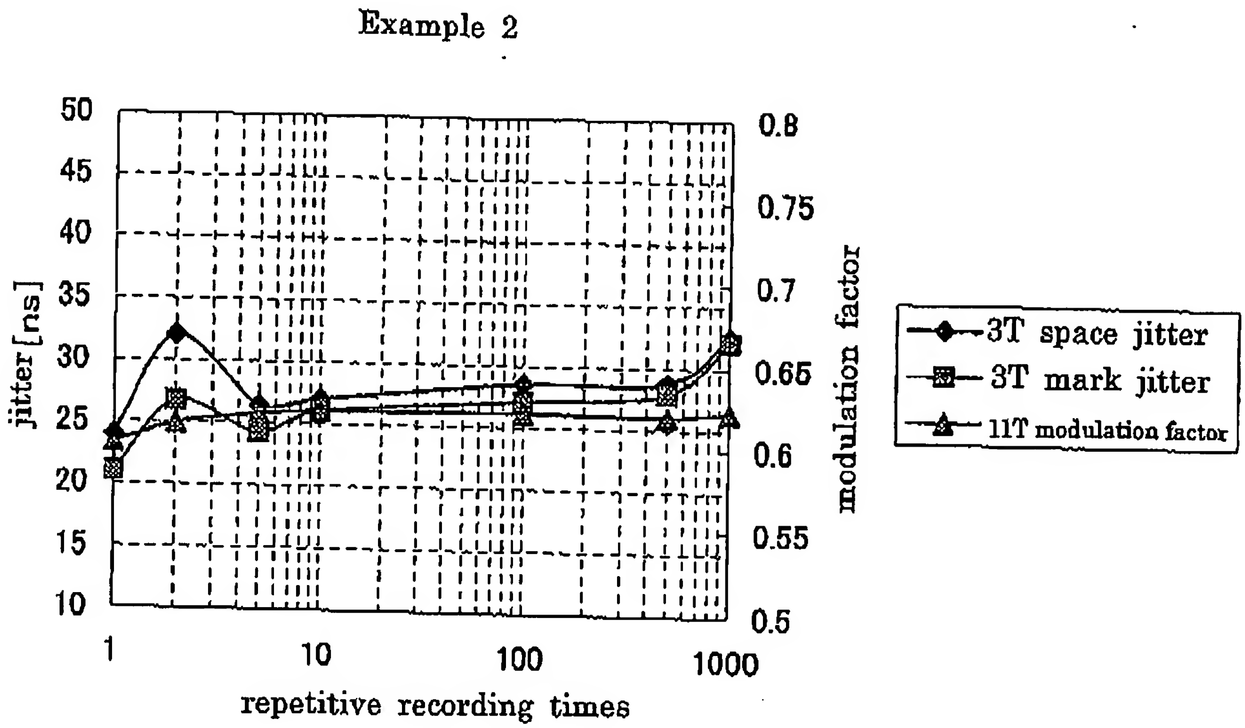


[FIG. 6]

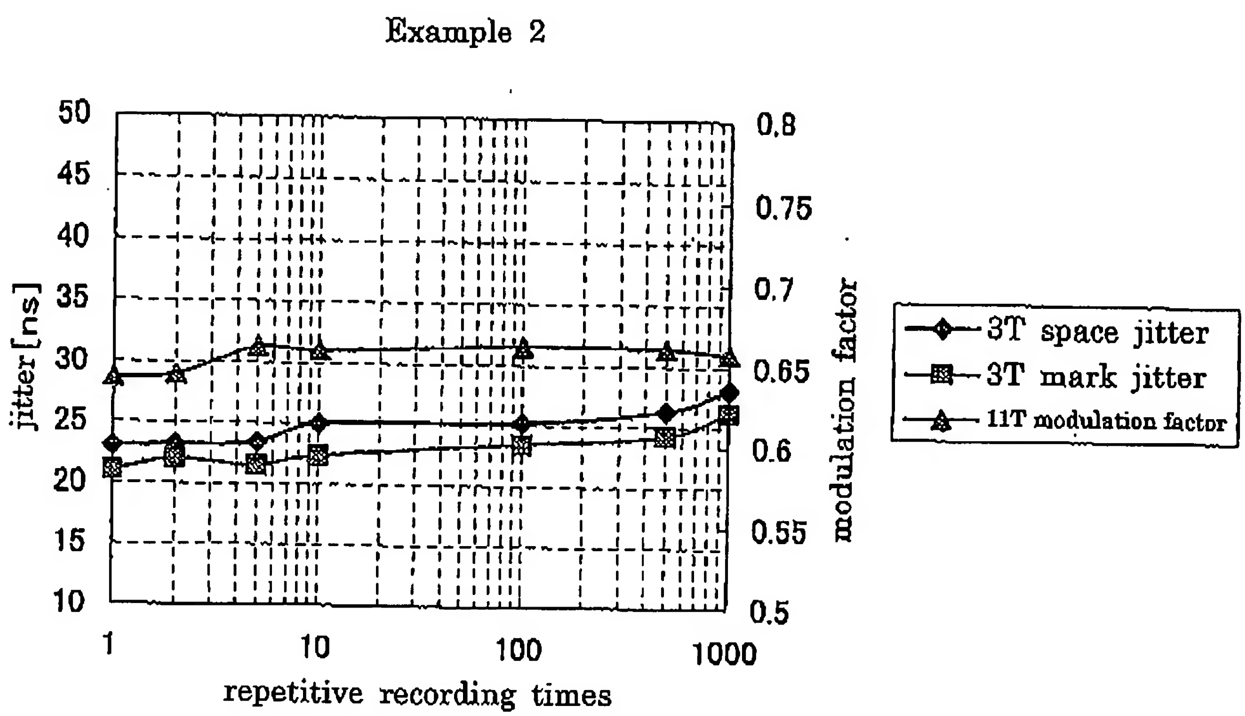
Example 1



〔FIG. 7〕


Example 2
50
45
40
35
30
25
20
15
10
jitter [ns]
0.8
0.75
0.7
0.65
0.6
0.55
0.5
modulation factor
1
10
100
1000
repetitive recording times
3T space jitter
3T mark jitter
11T modulation factor

〔FIG. 8〕


Example 2
50
45
40
35
30
25
20
15
10
jitter [ns]
0.8
0.75
0.7
0.65
0.6
0.55
0.5
modulation factor
1
10
100
1000
repetitive recording times
3T space jitter
3T mark jitter
11T modulation factor